Ministry
of
Transportation
Ontario

REPORT EM-96

Micro-Deval Test for Evaluating the Quality of Fine Aggregate for Concrete and Asphalt

Engineering
Materials
Office

June, 1991

91-05289/

TECHNICAL REPORT DOCUMENTATION PAGE

MICRO-DEVAL TEST FOR EVALUATING THE QUALITY OF FINE AGGREGATE FOR CONCRETE AND ASPHALT

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Abstract:

The sulphate soundness test has been used for many years for evaluating the physical suitability of fine aggregate. It suffers from poor within-laboratory and multi-laboratory precision and is time consuming and expensive. The work described here was an evaluation of alternative tests for measuring soundness of fine aggregate. The tests studied were the attrition test and a modified version of the French micro-Deval test usually used for coarse aggregate. The micro-Deval test was found to have a significant correlation with magnesium sulphate soundness loss and water absorption of fine aggregate. Unlike the attrition test, the micro-Deval test is relatively insensitive to the gradation of the sand being tested and has excellent precision. The test is conducted by placing 500 g of water saturated sand in a ball mill with 1250 g of 9.5 mm steel balls and 750 ml of water. The mill is rotated at 100 r.p.m. for 15 minutes. The aggregate is washed over a 75 micron sieve and the loss calculated as a mass per cent of the original oven dry weight. The test may be completed in less than 48 hours. Aggregates which give more than 25% loss are judged to be marginal for use in Portland cement concrete and asphaltic concrete. The Ontario Ministry of Transportation is adopting the micro-Deval test for measuring the quality of fine aggregate for concrete and asphalt.

Résumé:

Depuis de nombreuses années, l'essai de résistance au sulfate est utilisé pour évaluer les applications possibles des petits agrégats. La précision obtenue en laboratoire et dans d'autres laboratoires est faible; de plus, cet essai est long et coûteux. Les travaux décrits dans le présent document portent sur l'évaluation d'autres essais visant à mesurer la résistance des petits agrégats. On a etudié deux essais: l'essai par l'usure de frottement et une version modifiée de l'essai français micro-Deval généralement utilisé pour les gros agrégats. L'essai micro-Deval a demontré une corrélation importante entre la perte de résistance au sulfate de magnésium et la masse d'eau absorbée par les petits agrégats. Contrairement à l'essai par l'usure de frottement, l'essai micro-Deval est relativement insensible à la granularité du sable étudié et est très précis. On effectue cet essai en plaçant 500 g de sable saturé d'eau dans un broyeur à boulets contenant 1 250 g de billes d'acier de 9,5 mm et 750 ml d'eau. On règle le broyeur à 100 tours-minute et on le fait fonctionner pendant 15 minutes. Les agrégats sont lavés à l'aide d'un crible dont les trous mesurent 75 micromètres et la perte est calculée en pourcentage de masse du poids sec absolu initial. On peut effectuer cet essai en moins de 48 heures. On juge que les agrégats dont la perte est supérieure à 25 pour 100 sont faibles et ne peuvent être utilisés dans le béton de ciment portland et le béton asphaltique. Le ministère des Transports de l'Ontario adopte donc l'essai micro-Deval pour évaluer la qualité des agrégats fins destinés au béton et au bitume.

Keywords: aggregates, performance, micro-Deval, concrete, asphalt, testing, sulphate soundness test

Published by: ENGINEERING MATERIALS OFFICE
MINISTRY OF TRANSPORTATION
1201 Wilson Avenue
Downsview, ONTARIO
CANADA M3M 1J8

Date: June, 1991

Report Number: EM-96
ISBN 0-7729-8486-7

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MICRO-DEVAL TEST FOR EVALUATING THE QUALITY OF FINE AGGREGATE FOR CONCRETE AND ASPHALT

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THIS REPORT IS PUBLISHED WITHOUT PREJUDICE AS TO THE APPLICATION OF THE FINDINGS

MICRO-DEVAL TEST FOR EVALUATING THE QUALITY OF FINE AGGREGATE FOR CONCRETE AND ASPHALT

INTRODUCTION

In many areas of North America, especially near urban areas, it is recognized that construction aggregates are a depleting resource. The sterilization of resources by restrictive zoning regulations, building development and NIMBY (not in my back yard) groups further contribute to shortages of moderate cost aggregates. As a result, there is often pressure to use lower quality or marginal aggregate sources. At the same time, there is a demand from engineers to use higher quality aggregates than were used in the past. For instance, where higher truck tire pressures and axle loads are causing rutting of asphalt pavements made with natural sand and gravel aggregates, the solution is to use quarried aggregates, excluding some traditional sources. Higher traffic volumes call for the use of pavement surfacing aggregates of better frictional properties, again excluding some traditional sources. There is, thus, a conflict between development, which tends to reduce aggregate resources, and an increasing demand for high quality aggregates as a result of this development.

Aggregate testing and evaluation procedures and specifications have not kept pace with modern technology. Some of the testing procedures used today are not necessarily the best available for the evaluation of the suitability of aggregates. Aggregates are often rejected for certain uses when they fail to meet one or more specifications, yet the actual field performance in concrete or asphalt may be satisfactory. The automatic rejection of aggregates which fail to meet existing specification requirements can lead to a reduction in available aggregate resources. The use of tests with an improved correlation with field performance and better precision than some of the current tests will allow the selection of some of the so-called 'marginal' aggregates with greater assurance that they will be suitable.

One of the most commonly used aggregate tests in North America is the magnesium sulphate soundness test. The forerunner of the present magnesium sulphate soundness test was developed in 1828. The purpose was to simulate the forces generated by freezing water in building stone. In the early nineteenth century, there was no means of freezing water in the laboratory so this test served well. The magnesium sulphate soundness test has been used for many years for testing fine aggregate. The sulphate soundness test on fine aggregate unfortunately has a poor multi-laboratory precision. In repeated studies of the multi-laboratory variation in five Ministry of Transportation laboratories, it was found [1] that the average coefficient of variation was 10.5%, and the 95 per cent difference limits were 30% (over a range in values from 7 to 22% loss). In other words, in repeated testing of a sand with an average loss of 16%, the range in values reported by various laboratories will be from 13.6% to 18.4%, nineteen times in twenty. ASTM (C 88) does not give precision data for the fine aggregate test, but notes that: "Since the precision of this test method is poor... it may not be suitable for outright rejection of aggregates without confirmation from other tests more closely related to the specific service intended".

In the late 1970's, work by the Ontario Ministry of Transportation [2] found a significant correlation (r^2=0.65, n=89) between the wet attrition test of Davis *et al* [3] and sulphate soundness loss of fine aggregates. In the late 1980's, it was decided to study this relationship further in the testing program reported in this paper. It was thought that wet abrasion or attrition tests would be more precise and quicker than the sulphate soundness test,

and measure more or less the same properties as the soundness test. A number of wet abrasion tests were selected for study.

TESTING PROGRAM

ASTM Attrition Test

This test, first proposed by Davis, Mielenz and Polivka [3], has been adopted by ASTM (C 1137-90). It consists of placing a washed, graded, 500 g sample of sand in an eight sided container where it is subjected to vigorous abrasive action with a high speed impeller at 850 r.p.m. in the presence of 175 ml of water. Loss is measured by the decrease in fineness modulus or the increase in the amount of material passing the 75 µm sieve. In this study, the ASTM procedure was used with a WEMCO impeller and tank with the following modifications: Test duration was extended from six to ten minutes since six minutes seemed somewhat arbitrary and it was desired to cause significant loss in the test. The sands were washed over a 75 µm sieve and dried prior to testing but were not graded to a standard grading. Change in F.M. (fineness modulus) was not reported.

MTO Attrition Test

This test is similar to the ASTM attrition test. It has been used by the Ontario Ministry of Transportation (MTO) for ten years, for evaluating the objectionable mud producing properties of sand spread on icy road surfaces [2]. The impeller device, more robust than that used in the ASTM procedure, was that specified by Davis *et al.* [3]. A 500 g sample was tested in 175 ml of water for ten minutes at an impeller speed of 390 r.p.m. This speed was adopted several years ago because the 850 r.p.m. originally used by Davis *et al.* [3] was found to cause excessive splashing.

Micro-Deval Abrasion Test

This test has been developed in France [4, 5, 6] for the evaluation of coarse aggregate. It has since been adopted in the province of Québec [7]. It consists of abrading a sample of 500 g of stone with 5000 g of 9.5 mm diameter steel balls and 2.5 l of water in a 5 l steel jar, 200 mm in diameter. The jar is rotated at 100 r.p.m. for 2 hours. Loss is measured by measuring the amount of material passing a 1.25 mm sieve. For testing fine aggregate, the test was modified as follows: A 700 g sample of sand was washed on a 75 µm sieve and oven dried. A representative oven dry sub-sample of 500 ± 5 g was prepared and immersed in tap water at room temperature for 24 hours. Excess water was poured off and the sample placed in a steel jar with 1250 g of steel balls and 750 ml of water. The jar was rotated at 100 r.p.m. for 15 minutes. The sample was washed over a 75 µm sieve and oven dried to constant mass. Loss was expressed as percent by mass of the original sample mass.

Samples were also tested to determine their gradation, absorption, relative density and loss in the magnesium sulphate soundness test.

SAMPLE COLLECTION

Ideally, it would have been desirable to test a group of samples that had a field performance history ranging from good to bad. After over 40 years of experience, the Ministry of Transportation has never used a fine aggregate that caused or resulted in premature failure of concrete or asphalt that could be attributed to inadequate physical properties measured by the

sulphate soundness test. Asphalt pavements have failed due to unsatisfactory fine aggregate particle shape or unsatisfactory grading. Concrete has failed due to some alkali-silica reactive component in the sand, poor grading, or the presence of objectionable quantities of organic acids. It has not been possible to attribute failure to an unsatisfactory property measured in the sulphate soundness test. Fine aggregates that had a sulphate soundness loss of up to 45% have occasionally been used in asphaltic concrete without apparent failure. This experience created a problem in devising a satisfactory sampling system.

A number of natural sands and crusher screenings that are used in Ontario exceed the sulphate soundness requirements for various applications. The Ministry of Transportation has specifications for maximum magnesium sulphate soundness loss for concrete and asphalt fine aggregate. The limit for Portland cement concrete and high quality asphaltic concrete use is a maximum of 16% loss, and 20% for lower quality asphaltic concrete use. The specifications allow these limits to be exceeded if field performance of concrete or asphalt and/or results of accelerated freeze-thaw testing of concrete can be shown to be satisfactory. For instance, natural sands found in the vicinity of the Niagara Escarpment typically contain high amounts of cemented particles and porous sandy carbonates which result in sulphate soundness losses of up to 25%. It has been found that these sands perform well in asphalt and concrete and are approved and used for these applications [8]. In 1989, a Portland cement concrete supplier in Eastern Ontario was able to demonstrate that a natural sand performed well in concrete both in the field and in accelerated laboratory tests. Despite sulphate soundness losses of up to 25% this material was approved for use in Ontario highway work. There are other examples, particularly with the crusher screenings from carbonate quarries which typically give high sulphate soundness losses yet perform well in asphaltic concrete. The reason for their high losses is not exclusively due to any large amount of weak or otherwise unsound particles but is partly caused by the coarseness of gradation of these screenings, which in the test calculations, can unfairly penalize them. New York State has also recognized this problem with coarse sands giving high sulphate losses, and now calculates loss in this test using a standard grading, irrespective of the grading of the sand tested.

It was desired to test those sands that had a record of satisfactory field performance but exceeded the current specification limits since this would aid in setting specification limits for any new test that was adopted as a substitute for the sulphate soundness test. It was decided to select a suite of about 100 samples of fine aggregate that had a history of satisfactory performance in Portland cement concrete or asphaltic concrete or both. These were selected and sampled by highway engineers in the five administrative regions in Ontario. The location and nature of the samples and test results are presented in the appendix. The samples consisted of 86 natural sands and 21 quarry screenings. The quarry screenings were nearly all from Palaeozoic carbonate quarries in southern Ontario. The natural sands consisted either of 100% of siliceous particles of Precambrian age from northern Ontario, or mixtures of Precambrian siliceous particles and Palaeozoic sediments (carbonate, siltstone, sandstone, sandy carbonate and shale) found in southern Ontario.

RESULTS AND DISCUSSION

Sample Grading

The first task was an investigation of the influence of sample grading on degradation in the attrition/abrasion tests. A good quality natural sand and crusher screenings from a shaley limestone quarry were prepared to four different gradings (Figure 1). The fineness modulus (F.M.) varied from 2.15 to 3.77. Samples of these materials were then tested in the ASTM and MTO attrition tests and the micro-Deval test. Results are shown in Figure 2. It can be seen that

in the case of the attrition tests, the finer graded samples gave significantly lower losses than the coarse samples. In these tests, it is postulated that the larger particles have greater kinetic energy than the smaller particles, which led to greater disintegration on impact with the walls of the container. Alternatively, larger particles may simply be less resistant to damage than smaller particles. This observation indicated that, in future development, samples should be tested at a standard grading to remove the bias introduced by either coarser or finer gradings. In contrast, the micro-Deval test showed a negligible or reverse response. The finer the grading of the sample, the greater the loss. This influence of grading was relatively small at low losses (< 20%), but became more obvious with higher loss materials. In contrast to the attrition test, this test is conducted at low speed . The particles have little kinetic energy and the main means of disintegration is a grinding action between the particles and between the particles and the steel balls. In this case, it would be expected that the amount of break down would be a direct function of energy expended and also the original size of the particles. Less work has to be done on a fine than on a coarse graded sample to cause material to break down to pass the 75 µm sieve. This observation was confirmed by testing a further eight different materials at the four different gradings.

Variability

The within-laboratory variability of the three tests was determined by testing ten replicate samples of natural sand and shaley limestone screenings. The results are shown in Table 1. It can be seen that the ASTM attrition tests gave the highest loss with the shaley limestone, but also had a wide variation. With the low loss natural sand, the MTO attrition test has the widest variation but this is mainly due to the very low mean loss of 4.1% obtained in this test with this material, which distorts variability when using coefficient of variation. The micro-Deval test had the lowest within-laboratory variation of about 1 to 2%.

	NATURAL SAND		SHALEY LIMESTONE SCREENINGS	
	Mean loss	C of V.	Mean loss	C of V.
micro-Deval	13.8%	1.9%	23.4%	1.1%
ASTM Attrition	13.3%	11.0%	38.8%	6.8%
MTO Attrition	4.1%	14.1%	20.1%	5.4%

Number of replicates = 10, C of V = coefficient of variation

Table 1. Within-Laboratory Variability of Attrition and micro-Deval Tests.

The micro-Deval test was thus found to be relatively insensitive to sample grading and also to have the lowest within-laboratory variation. These two attributes are much desired. The requirement to prepare samples to a standard grading prior to testing is time consuming and expensive. In the case of very fine or very coarse materials, large amounts of material must be sieved to obtain the desired standard grading. In some cases, such as with fine sands, it is difficult to obtain enough coarse material to make up a sample to a standard grading. In any event, such a sample can hardly be representative.

In order to investigate likely multi-laboratory variation in the micro-Deval test, an experiment was devised. Replicate samples of 58 different materials were tested in different equipment at different times by different technicians. The micro-Deval loss of the materials ranged from five to 31%. The average coefficient of variation was found to be 3.2%. In practical terms, this means that testing of replicate samples of a material with a mean loss of 20% in different experienced laboratories might be expected to give results between 18.2 and 21.8 %, 95% of the time. This is a wider variation than found in the within-laboratory investigations (Table 1) but is still excellent compared to many other materials tests.

In spite of the marked effect of grading on loss in the attrition tests, they were initially conducted without using a standard grading. The samples were washed, dried and prepared to 500 g, but no attempt was made to grade the material to a constant grading. It was desired to see if, despite the effect of grading on loss, any useful relationship existed between these tests. Figure 3 shows the relationship between the ASTM and MTO attrition tests. As should be expected, there is an excellent correlation, but there is a marked difference in performance in the two tests. On average, there is about three times more loss in the ASTM attrition test. This is due to the higher speed of the impeller (850 r.p.m.) in this test compared to the MTO test (390 r.p.m.). Over the course of testing, it was found that there was considerable wear on the ASTM impeller and this had a marked effect on loss in the test. Periodically replicate samples of standard laboratory sands were tested. There was a consistent and gradual reduction in loss in this test from the start of the program to completion, for both shaley limestone screenings and for natural sand (Figure 4). After about 100 samples had been tested, a new impeller was fitted to the ASTM attrition device and loss of these reference materials increased to the original values. In any future development of the ASTM attrition test, this problem will have to be compensated for. The MTO attrition test, because more robust blades are mounted on the impeller, did not show this problem and results of testing replicate samples remained consistent throughout the program.

Correlation With Sulphate Soundness

Figure 5 shows the relationship between the ASTM attrition test and magnesium sulphate soundness loss. There is a significant correlation for both natural sands and screenings. The attrition loss of the screenings was considerably greater than that for natural sands. This is probably due to the coarser gradation of screenings compared with natural sands. Had testing been conducted at constant grading such a marked difference would not have been observed. There is, however, a useful relationship that could be used to predict sulphate soundness loss. In a supplementary experiment, 64 natural sands and screenings were prepared to a constant grading (F.M.=2.78) and attrition loss was compared with sulphate soundness loss. The results are shown in Figure 6. The improved correlation coefficient of 0.81 compared with that obtained without using a variable grading (Figure 5) shows the importance of particle size in determining loss in the attrition test.

The relationship between micro-Deval loss and magnesium sulphate soundness loss of all samples is shown in Figure 7, that for concrete sands in Figure 8, and that for asphalt sands and screenings in Figure 9. It can be seen that there is an excellent correlation for both natural sands and for crusher screenings. In Figures 8 and 9, proposed new requirements are shown for various applications. In Figure 9 the proposed requirement for HL (hot laid) 1 and 3 fine aggregates refers to the highest quality asphaltic concrete used exclusively for surface courses. The requirements for HL 2, 4 and 8 refer to lower quality asphaltic concrete used in surface courses on secondary highways and in binder courses. In May 1990, on an experimental basis, these requirements were adopted for Ontario highway contracts in Central Region. It will be seen that adoption of these new criteria will result in the acceptance of some materials that had previously not met the soundness requirements. This is intentional. At the time materials were

selected for testing, it was specified that the fine aggregates should be those currently used on MTO work, even if they exceeded the current soundness specifications. These materials had a record of having been used without any known or obvious deleterious effect, so an adjustment to selection criteria is justified, in the absence of any record of failure due to properties measured by the sulphate soundness test.

It was desired to see how reliable the micro-Deval test was at measuring the quantity of low quality material in an otherwise satisfactory sand. A low strength, slaking shale (Queenston) was oven dried, crushed and sieved. This shale was then blended with a high strength quartz sand (from Ottawa, Illinois) at various levels of substitution. The results are shown in Figure 10 and show an excellent relationship between amount of shale and loss in the test.

A significant correlation was found between water absorption and performance in the various tests. In the wet attrition/abrasion tests this is probably partly due to a slaking effect. Material that is susceptible to slaking has a high micro-porosity (shales, clays and shaley limestones). It can also be argued that the more porous materials will generally be weaker and break down more readily when subjected to abrasion or attrition. The correlation (r^2=0.81, n=58) between natural concrete sand and micro-Deval loss in Figure 11 is particularly striking. A significant correlation was also found between water absorption and magnesium sulphate soundness loss for concrete sands (r^2= 0.67, n=58), and between water absorption and ASTM attrition loss for concrete sands (r^2= 0.65, n=58). Adams and Pratt [9], Mather [10], and Chamberlin [11] all found high positive correlations between water absorption of natural sands and loss in magnesium sulphate soundness tests (r^2=0.81, 0.81 and 0.82 respectively). This relationship is logical, since the higher the porosity, the more sulphate solution that can enter the particles and exert destructive pressure when crystallized in the drying cycle of the test.

IMPLEMENTATION

A detailed procedure for the micro-Deval test has been written [MTO LS-619]. A feature of the test is a requirement to periodically test a reference material to observe and control within and between-laboratory variation. It is intended that after every nine samples are tested, a tenth sample, which is the reference aggregate, should be tested and results plotted on a control chart (Figure 12). If a laboratory only rarely conducts the test, then testing of the reference aggregate should be conducted whenever the test is performed. MTO has purchased a fifteen tonne stockpile of slightly shaley limestone screenings which is being used as a reference material. The procedure also calls for testing aggregates using the original grading of the sample with the +4.75 mm particles removed. In cases of dispute, however, the procedure calls for testing at a standard fineness modulus of 2.8 with a specified grading.

CONCLUSIONS

The magnesium sulphate soundness test for fine aggregate has a poor multi-laboratory precision and is not always suitable if rigid specification criteria are applied. The test is time consuming, taking 10 days.

The micro-Deval test is a rapid, simple test. Results can be obtained within two days. It has good correlation with the sulphate soundness test. The predicted within-laboratory and multi-laboratory variability of the micro-Deval test is good and can be easily controlled using a

reference material. The test is suitable for identifying fine aggregates that contain significant amounts of poor or weak rock types.

ACKNOWLEDGEMENTS

The observations described in this paper are the result of dedicated, painstaking work by many people who assisted with various tasks from the initial sample collection through to the final typing. We wish to thank the following for their assistance: C. Barber; E. Betts; D. Boothe; R. DuBois; L. Denomme; J. Dumond; D. Fox; G. Gage; M. Gibbens; K. Junor; B. Smith; H. Stankaitis; and G. VanKan.

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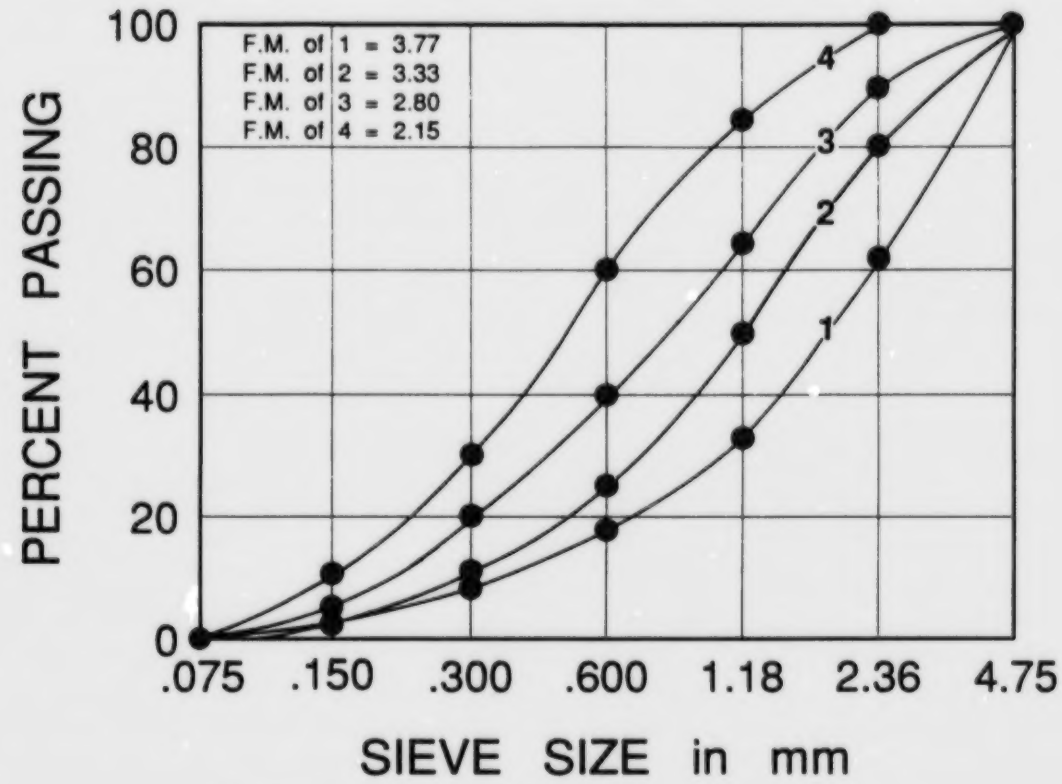


Figure 1: Gradations used to investigate the influence of particle size on performance in attrition/abrasion tests.

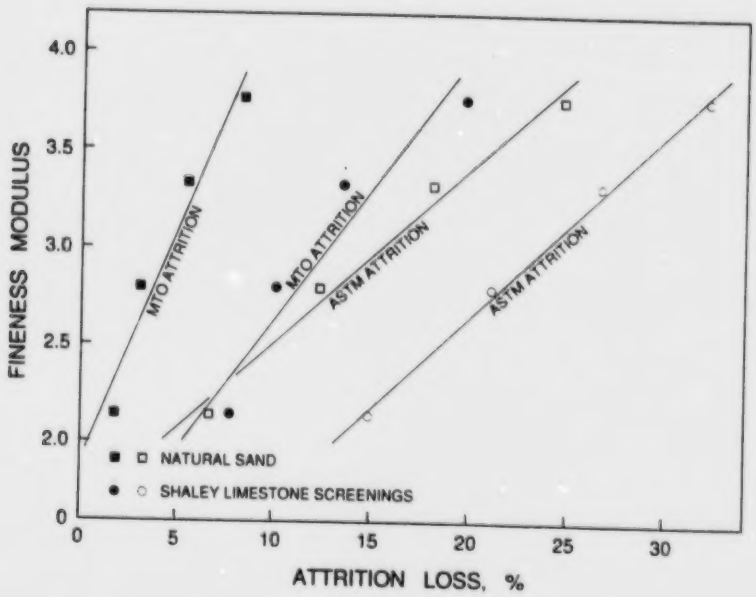


Figure 2A: Attrition loss against fineness modulus of sand and screenings.

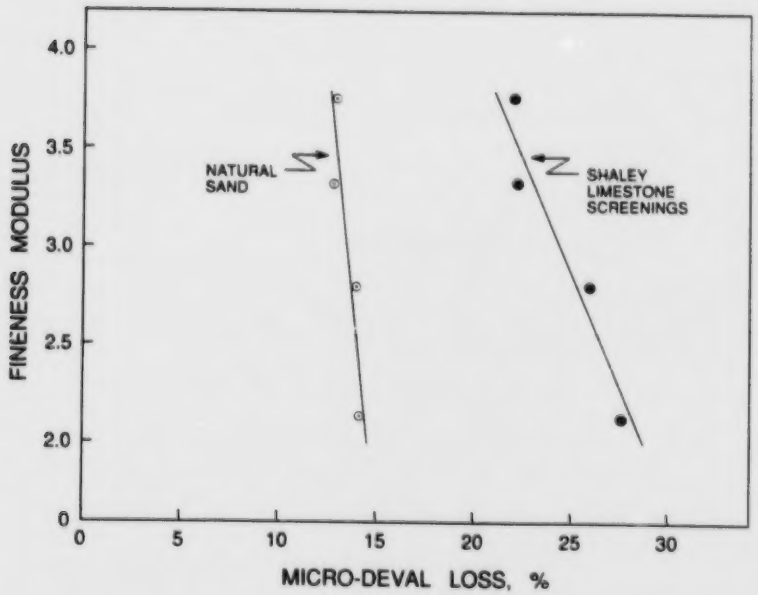


Figure 2B: micro-Deval loss against fineness modulus of sand and screenings.

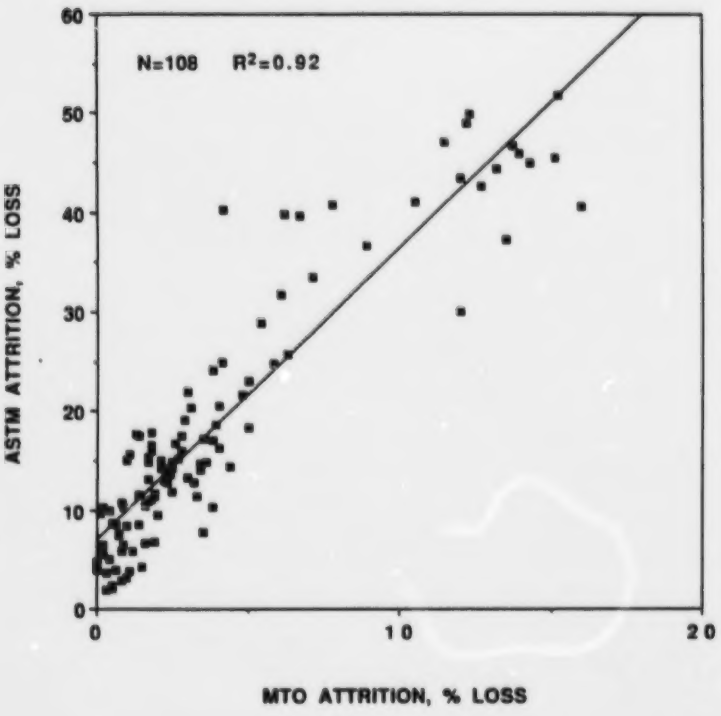


Figure 3: ASTM attrition loss versus MTO attrition loss for sands and screenings.

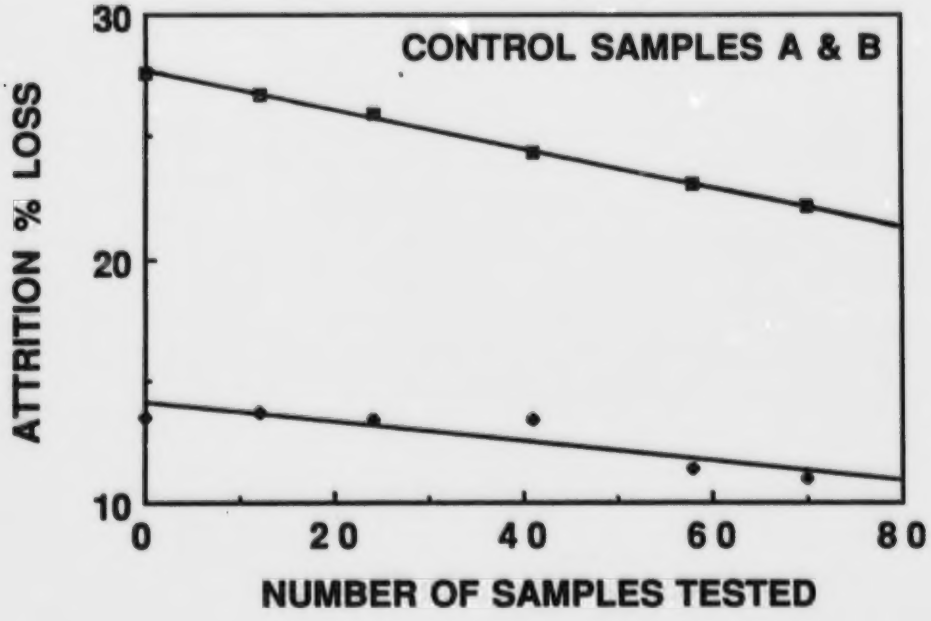


Figure 4: ASTM attrition loss of two control samples is reduced with time, due to wear on the impeller blades.

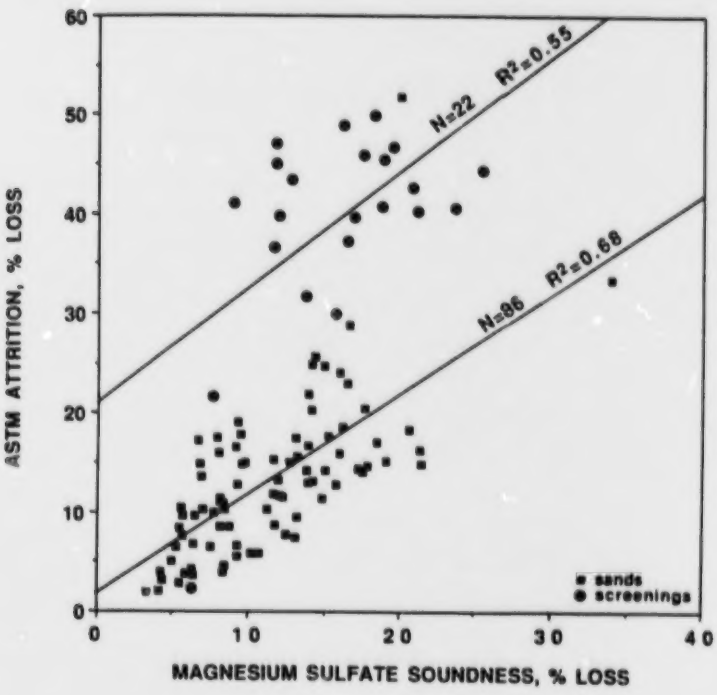


Figure 5: ASTM attrition loss against magnesium sulphate soundness loss.

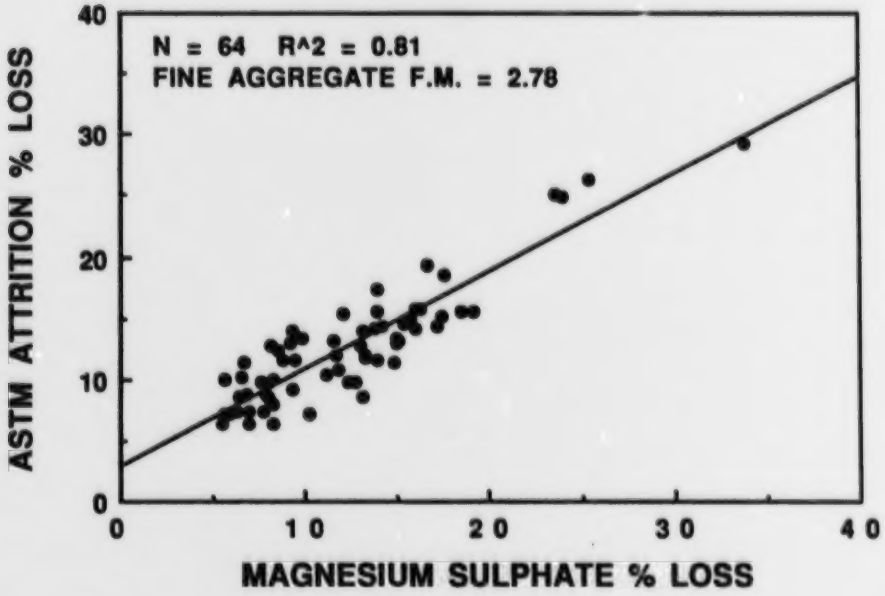


Figure 6: Attrition loss against sulphate soundness loss for sands and screenings prepared at an fineness modulus of 2.78.

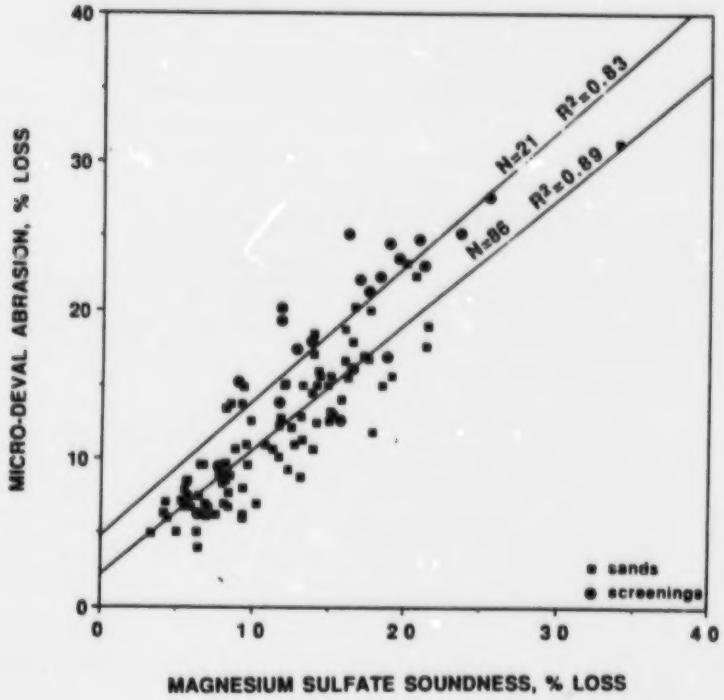


Figure 7: Micro-Deval abrasion loss against magnesium sulphate soundness loss for sands and screenings.

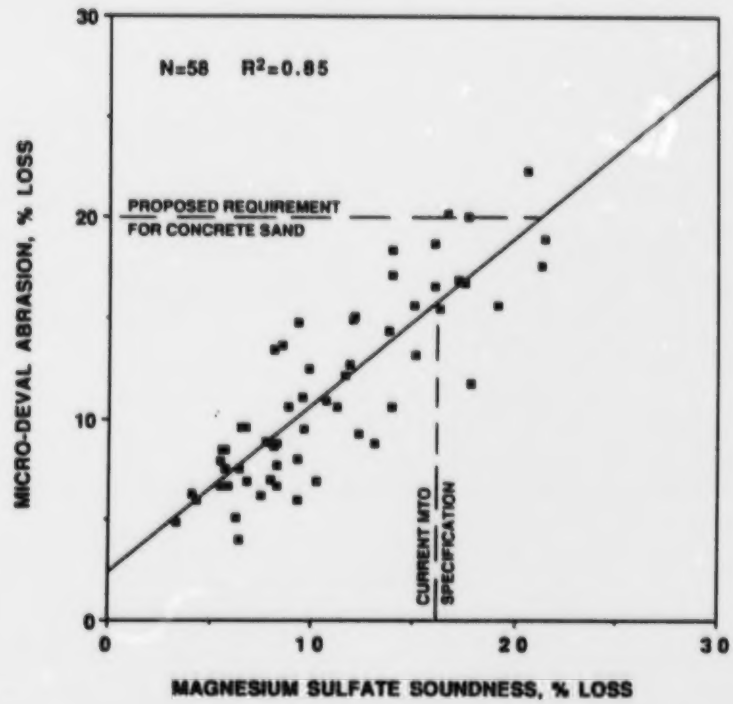


Figure 8: Micro-Deval abrasion loss against magnesium sulphate soundness loss for concrete sands.

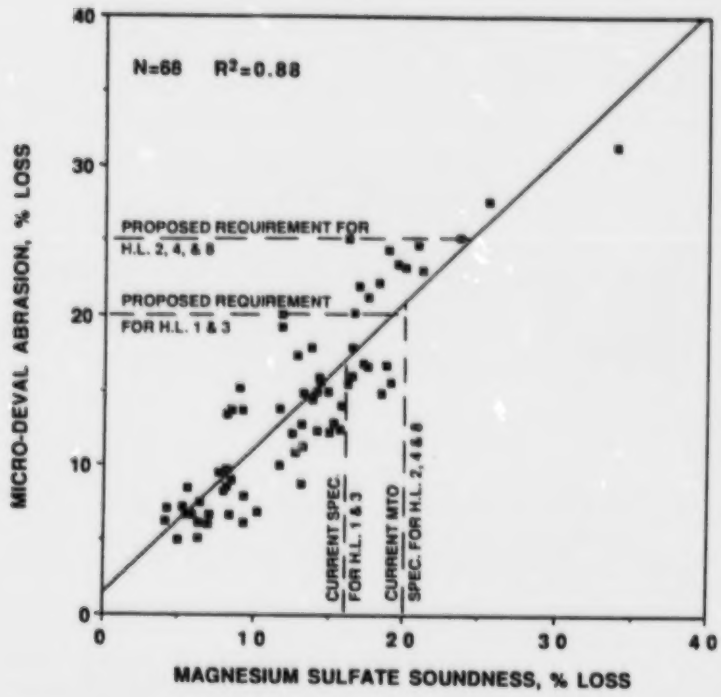


Figure 9: Micro-Deval abrasion loss versus magnesium sulphate soundness loss for asphalt sands and screenings.

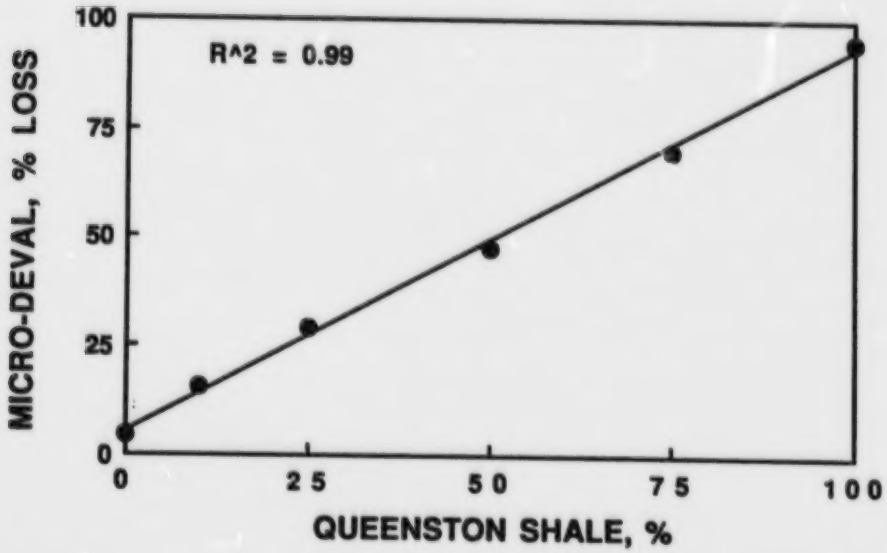


Figure 10: Micro-Deval loss against amount of low strength Queenston shale in quartz sand.

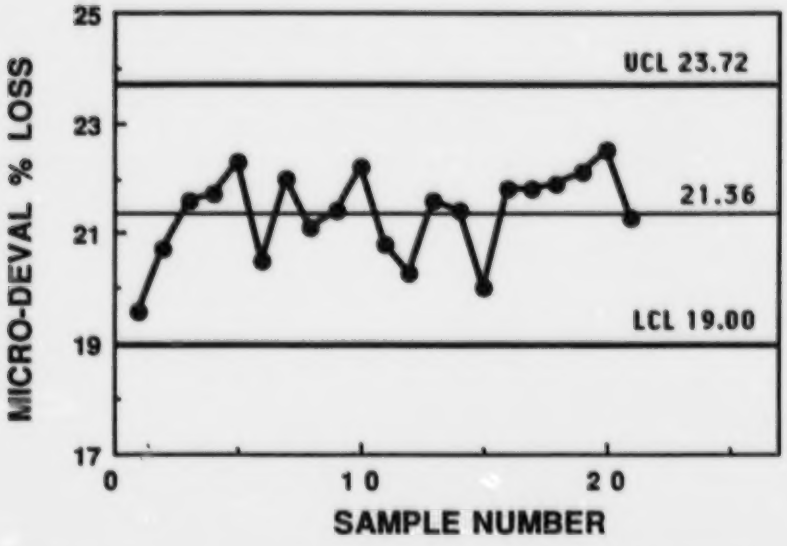


Figure 11: Results of repeated testing of a control sample of slightly shaley limestone screenings.

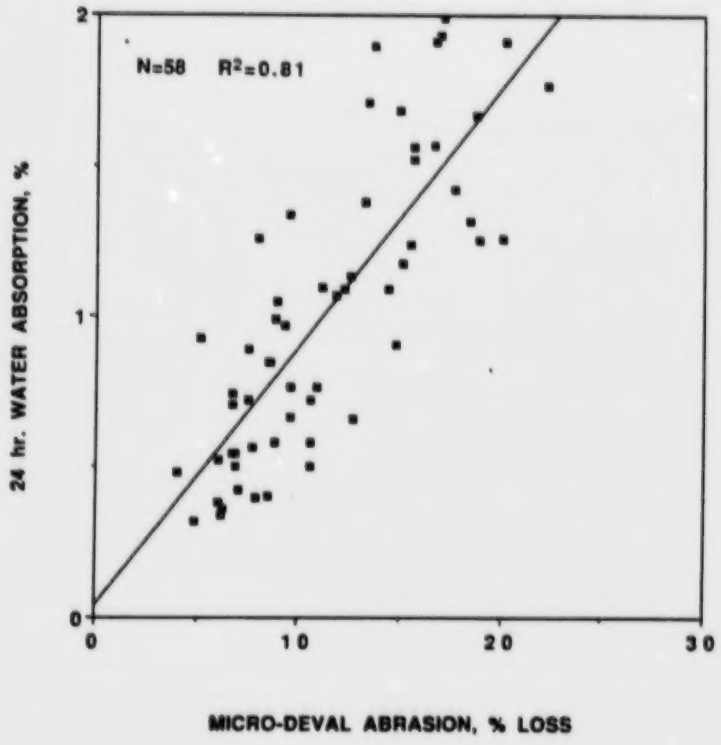


Figure 12: 24 hr. water absorption against micro-Deval abrasion loss for concrete sands.

APPENDIX

SAMPLE LOCATION MAPS, SAMPLE LOCATION AND USE DATA, DETAILED TEST RESULT DATA AND MICRO-DEVAL TEST PROCEDURE.

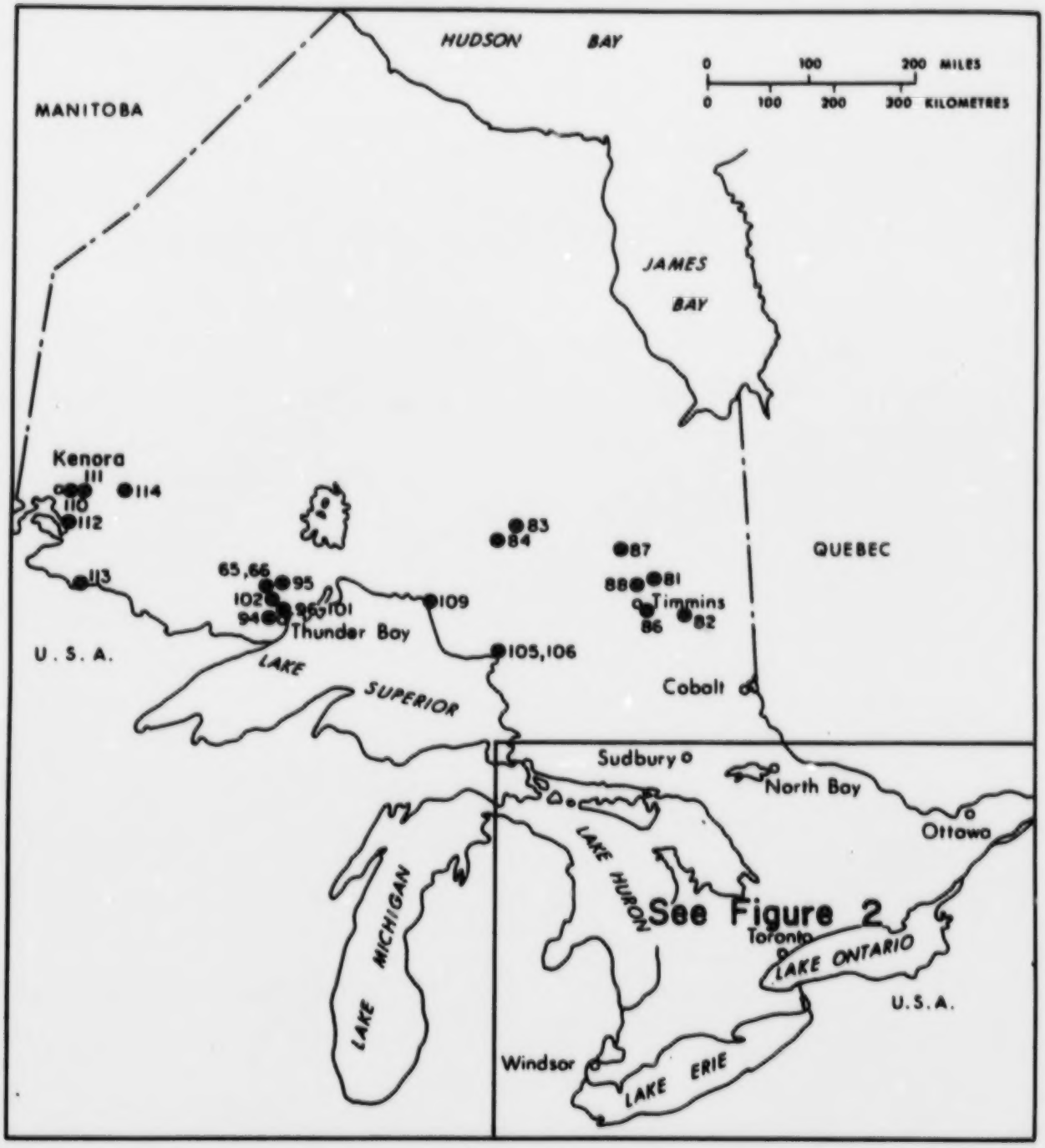


Figure 1: Sample location map.

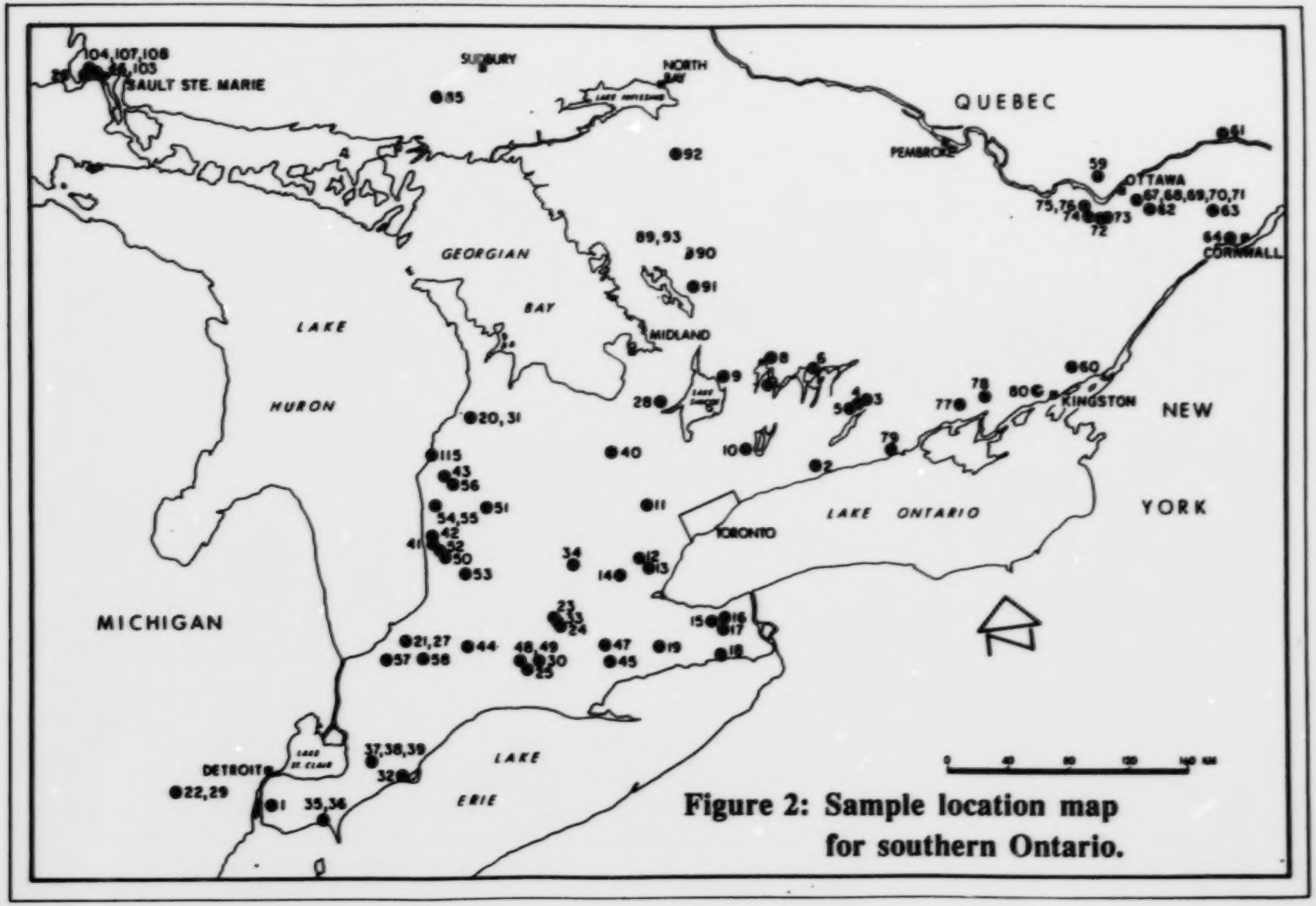


Figure 2: Sample location map for southern Ontario.

Sample Location Data

Sample No.	Source	Prior Use	Inventory No.	Map Location No.
88-9024	General Chem.	Asphalt sand	A11-009	1
88-9100	Harnden & King	Concrete sand	P13-011	2
88-9101	3M Canada Inc.	Asphalt sand	C01-054	3
88-9102	Drain Bros. Exc.	Asphalt sand	C01-064	4
88-9103	Warren Bitulithic	Asphalt sand	C01-005	5
88-9104	Ormell Sa. & Gr.	Asphalt screenings	B09-003	6
88-9105	Ormell Sa. & Gr.	Asphalt sand	F06-022	7
88-9106	Cedarhurst Quarries Ltd.	Asphalt screenings	F06-056	8
88-9107	Miller Paving/Vicdom Qry.	Asphalt screenings	O11-123	9
88-9108	Vicdom Sa. & Gr.	Concrete sand	N02-124	10
88-9109	United Aggregate (Armbro)	Asphalt sand	B10-121	11
88-9110	United Aggregate (Armbro)	Asphalt screenings	G09-067	12
88-9111	Dufferin Aggregates	Asphalt screenings	B12-127	13
88-9112	Dufferin Conc. Agg.	Concrete sand	C44-085	14
88-9113	Nelson Aggregate	Asphalt screenings	N03-035	15
88-9114	Vineland Quarry	Asphalt screenings	N03-023	16
88-9115	T.C.G. Materials (Fonthill)	Conc. & Asph. sand	N03-026	17
88-9116	Hardrock Paving	Asphalt screenings	W03-002	18
88-9117	Cayuga Quarry	Asphalt screenings	D05-020	19
88-9118	E.C. King	Concrete sand	C21-039	20
88-9119	R.A. Hume Cont. Ltd.	Concrete sand	P04-123	21
88-9120	Whitaker-Gooding	Concrete sand	U01-021	22
88-9121	Marshall Aggregate	Conc. & Asph. sand	W11-013	23
88-9122	Oxford Sa. & Gr.	Conc. & Asph. sand	W11-114	24
88-9123	Walmsley Bros. Ltd.	Asphalt sand	T03-044	25
88-9124	Granulated B.F. Slag (Algoma)	No MTO use	S10-038	26
88-9125	R.A. Hume Cont. Ltd.	Concrete sand	P04-123	27
88-9126	C. Varcoe Ltd.	Concrete sand	B03-100	28
88-9127	Whitaker-Gooding	Concrete sand	U01-021	29
88-9128	P. Vanryswyck	Asphalt sand	W11-062	30
88-9129	E.C. King	Concrete sand	C21-039	31
88-9130	R. Cleveland	Asphalt sand	C08-060	32
88-9131	Thorton Sa. & Gr.	Asphalt sand	W11-026	33
88-9132	Teeswater (Bauman)	Concrete sand	C12-020	34
88-9133	Erie Sa. & Gr.	Conc. & Asph. sand	E02-020	35
88-9134	Erie Sa. & Gr.	Conc. & Asph. sand	E02-020	36
88-9135	Huron Gravel	Asphalt sand	C08-003	37
88-9136	Huron Gravel	Asphalt sand	C08-003	38
88-9137	Adams Sa. & Gr.	Asphalt sand	C08-004	39
88-9138	Albion Sa. & Gr. (Dufferin)	Asphalt sand	D04-020	40
88-9139	Huron Concrete Supply	Conc. & Asph. sand	G04-057	41
88-9140	Verdon-Bradley-Vanstone	Asphalt screenings	G04-115	42
88-9141	Fe-Mor Holdings	Asphalt sand	W01-111	43
88-9142	Balmoral Farms	Concrete sand	L07-014	44

Sample Location Data

Sample No.	Source	Prior Use	Inventory No.	Map Location No.
88-9143	Cayuga Quarries	Concrete sand	S06-085	45
88-9144	A.B. McLean	Concrete sand	S10-051	46
88-9145	Waterford Sa. & Gr.	Concrete sand	S06-043	47
88-9146	Standard Aggregates	Concrete sand	L07-149	48
88-9147	Standard Aggregates	Asphalt sand	L07-149	49
88-9148	Lakeland Sa. & Gr.	Concrete sand	G04-026	50
88-9149	Donnegan	Concrete sand	W09-068	51
88-9150	Lavis Const.	Asphalt sand	G04-006	52
88-9151	Huron Concrete Supply	Concrete sand	S04-010	53
88-9152	Johnston Bros.	Asphalt sand	L08-060	54
88-9153	Johnston Bros.	Asphalt sand	L08-060	55
88-9154	Teeswater Const.	Concrete sand	W09-041	56
88-9155	K & E Sa. & Gr. (Edgewater)	Asphalt sand	S01-045	57
88-9156	Van der Kant Sa. & Gr.	Concrete sand	P04-143	58
88-9157	Dufferin Agg. & Asphalt	Concrete sand	O05-094	59
88-9158	Sweets Sa. & Gr.	Concrete sand	G02-092	60
88-9159	Malo, Plaisance, PQ	Concrete sand	T05-045	61
88-9160	Redmond Sa. & Gr.	Concrete sand	O05-110	62
88-9161	MacLeod Quarry	Asphalt screenings	C13-178	63
88-9162	Permanent Concrete	Asphalt screenings	C13-029	64
88-9163	KAM Aggregates	Concrete sand	S20-037	65
88-9164	KAM Aggregates	Concrete sand	S20-037	66
88-9165	Spratt's Sa. & Gr.	Concrete sand	O05-114	67
88-9166	Dibblee Constr. (Boyce Qry.)	Asphalt screenings	O05-070	68
88-9167	Armbro Aggregate	Asphalt screenings	O05-072	69
88-9168	Armbro Aggregate	Asphalt screenings	O05-072	70
88-9169	Beaver Asphalt (Miller Qry.)	Asphalt screenings	O05-067	71
88-9170	McFarland	Asphalt screenings	O05-108	72
88-9171	Burnside Sa. & Gr.	Concrete sand	K03-076	73
88-9172	Spratt's Sa. & Gr.	Asphalt screenings	O05-009	74
88-9173	Spratt's Sa. & Gr.	Concrete sand	A05-129	75
88-9174	Spratt's Sa. & Gr.	Asphalt sand	A05-129	76
88-9175	Long Quarry-McFarland	Asphalt screenings	B08-015	77
88-9176	Permanent Concrete	Asphalt screenings	S15-004	78
88-9177	Trent Valley Sa. & Gr.	Concrete sand	T07-048	79
88-9178	Dibblee Constr. Quarry	Asphalt screenings	S15-129	80
88-9179	MTO 641	Conc. & Asph. sand	P25-021	81
88-9180	MTO 235	Conc. & Asph. sand	K08-001	82
88-9181	MNR Kabina	Conc. & Asph. sand	C38-001	83
88-9182	MTO Red Pine	Conc. & Asph. sand	A24-003	84
88-9183	L.A. Brash	Conc. & Asph. sand	E01-028	85
88-9184	MTO Gibson Lk. Rd.	Conc. & Asph. sand	P25-051	86
88-9185	LaBelle	Conc. & Asph. sand	C24-020	87
88-9186	Esker Gran. Prod. (Stringer)	Conc. & Asph. sand	P02-042	88

Sample Location Data

Sample No.	Source	Prior Use	Inventory No.	Map Location No.
88-9187	Muskoka Cont. Services	Conc. & Asph. sand	O08-058	89
88-9188	Hutcheson Sa. & Gr.	Conc. & Asph. sand	H05-009	90
88-9189	Fowler-Cavalcade Estates	Conc. & Asph. sand	B17-034	91
88-9190	Ciglen #1 (Armbro)	Conc. & Asph. sand	S30-013	92
88-9191	K. Stoneman	Asphalt sand	O08-069	93
88-9222	Hacquoil (Stanley Pit)	Asphalt sand	K17-006	94
88-9223	KAM Aggregates	Concrete sand	S20-037	95
88-9224	Lempiala Sa. & Gr.	Concrete sand	O12-013	96
88-9225	Inkonen's Pit	Asphalt sand	O12-005	97
88-9226	Towland-Hewitson (Alander)	Asphalt screenings	O12-004	98
88-9227	Bruno's Constr. Ltd.	Asphalt sand	O12-085	99
88-9228	Bruno's Mapleward Pit	Asphalt sand	O12-026	100
88-9229	Inkonen's Pit	Asphalt sand	O12-005	101
88-9230	Laine Pit (Irwin Rdy. Mix)	Concrete sand	O12-080	102
88-9231	A.B. McLean	Concrete sand	S10-051	103
88-9232	Sault Concrete	Concrete sand	S10-040	104
88-9233	Harry Miller Const. Ltd.	Concrete sand	M41-022	105
88-9234	Rail Pit MTO	Asphalt screenings	M41-001	106
88-9235	Towland-Hewitson (McQueen)	Asphalt sand	S10-045	107
88-9236	Ellwood Robinson Asphalt	Asphalt sand	S10-090	108
88-9237	Permanent Concrete	Concrete sand	M12-023	109
88-9238	Towland-Hewitson	Asphalt sand	K04-023	110
88-9239	Northwestern Concrete	Concrete sand	K04-013	111
88-9240	MTO Kenora - Caviar Lake	Asphalt sand	C42-011	112
88-9241	Armstrong Pit	Concrete sand	F05-001	113
88-9242	R. Kellar-Pearson Pit	Concrete sand	D12-032	114
88-9243	MTO 275	Asphalt sand	K06-021	115

SAMPLE	P 75 um	FM P 4.75 mm	MDA LOSS	MTO ATT.	ASTM ATT.	MgSO4 LOSS	ABS.	BULK Dr.
9024	14.6	3.09	23.2	15.2	51.8	20.0	1.900	2.580
9100	2.9	2.48	9.6	0.1	9.7	6.5	0.664	2.658
9101	1.5	2.13	12.1	3.5	7.7	12.5	1.212	2.872
9102	2.5	2.78	14.9	3.8	17.0	18.5	1.235	2.645
9103	2.3	2.47	14.0	2.3	12.8	15.8	0.685	2.667
9104	8.1	3.45	16.0	13.5	37.2	16.5	0.805	2.658
9105	1.5	2.59	10.1	2.5	11.9	11.7	0.705	2.648
9106	9.6	3.46	24.4	15.1	45.5	18.9	1.045	2.634
9107	12.7	2.96	27.6	13.2	44.4	25.5	1.373	2.614
9108	1.0	2.35	10.6	1.4	8.5	8.8	0.582	2.665
9109	0.8	2.60	11.3	2.0	9.4	13.2	0.703	2.654
9110	14.7	2.81	-	6.2	39.8	12.0	0.665	2.779
9111	12.7	2.88	22.0	6.7	39.6	16.9	0.624	2.783
9112	3.5	2.71	20.0	4.0	20.6	17.6	1.256	2.719
9113	14.1	3.03	24.7	12.7	42.7	20.8	1.688	2.708
9114	16.7	2.82	23.0	4.2	40.3	21.1	0.864	2.759
9115	2.0	2.55	15.6	2.7	15.1	19.1	1.519	2.594
9116	7.6	3.35	25.2	16.0	40.6	23.6	1.436	2.697
9117	3.8	3.99	12.5	12.0	30.0	15.7	1.992	2.686
9118	1.4	3.09	12.5	2.1	15.0	9.8	1.129	2.671
9119	1.9	2.56	14.9	3.0	13.2	12.0	1.683	2.606
9120	1.2	2.64	8.9	0.4	10.0	7.7	1.047	2.629
9121	2.7	3.10	15.5	3.9	18.6	16.2	1.234	2.643
9122	1.4	2.91	14.4	2.4	14.2	13.8	1.089	2.658
9123	3.6	2.76	13.7	1.8	16.6	9.2	1.232	2.634
9124	1.2	2.99	5.0	2.7	6.2	25.7	1.337	2.379
9125	2.0	2.55	15.6	2.5	14.2	15.0	1.560	2.605
9126	0.8	2.74	7.9	1.0	8.4	5.5	0.400	2.672
9127	1.0	2.73	8.8	0.8	10.8	8.3	0.988	2.633
9128	5.0	2.36	14.9	1.1	15.7	13.2	1.109	2.646
9129	1.4	3.07	12.2	1.7	15.3	11.6	1.090	2.677
9130	3.6	2.62	31.3	7.1	33.4	33.9	3.703	2.429
9131	2.5	2.41	15.9	1.7	13.1	14.2	1.395	2.628
9132	2.3	2.98	22.3	5.0	18.3	20.6	1.764	2.625
9133	0.7	2.61	16.7	3.4	14.1	17.5	1.911	2.556
9134	0.6	2.48	16.9	4.4	14.4	17.2	1.933	2.548
9135	2.9	2.78	12.8	1.4	17.5	13.1	1.252	2.608
9136	3.3	2.72	12.9	1.3	17.7	15.3	1.170	2.615
9137	3.1	3.05	12.4	3.1	20.3	14.1	1.292	2.613
9138	4.2	2.83	10.9	1.0	15.0	12.7	1.129	2.623
9139	4.5	3.02	20.2	5.4	28.6	16.6	1.911	2.594
9140	8.7	3.05	17.9	6.1	31.7	13.7	1.724	2.621
9141	1.7	3.52	15.0	4.1	24.9	14.1	2.183	2.602
9142	1.1	2.90	14.8	2.9	19.1	9.3	0.907	2.640
9143	0.2	2.38	10.9	0.8	5.8	10.7	0.764	2.657
9144	0.7	2.35	4.0	0.3	3.7	6.4	0.481	2.660

Note 1

	SAMPLE	P 75 um	FM P 4.75 mm	MDA LOSS	MTO ATT.	ASTM ATT.	MgSO4 LOSS	ABS.	BULK Dr.
	9145	1.6	2.18	12.7	0.5	8.7	11.8	0.662	2.666
	9146	1.8	2.49	15.1	1.9	11.7	12.1	1.173	2.638
	9147	0.8	2.79	15.0	1.9	11.4	14.8	1.252	2.634
	9148	2.7	3.12	16.6	3.8	24.2	16.0	1.564	2.641
	9149	3.0	2.92	17.1	3.0	22.0	13.9	1.992	2.620
	9150	2.8	3.03	17.9	5.0	23.1	16.5	2.119	2.579
	9151	2.1	2.47	18.4	2.6	16.7	13.9	1.316	2.631
	9152	4.2	3.28	15.6	6.3	25.8	14.3	2.054	2.595
Note 2	9153	2.2	1.13	11.8	-	2.6	6.0	0.742	2.652
	9154	1.7	2.37	18.7	1.8	15.9	16.0	1.667	2.620
	9155	1.5	1.78	9.7	0.6	8.5	8.1	1.028	2.600
	9156	2.3	2.80	13.2	2.1	14.2	15.1	1.375	2.608
	9157	2.5	2.31	9.3	1.4	11.5	12.3	0.969	2.642
	9158	1.3	2.70	11.8	3.4	14.7	17.8	1.068	2.646
	9159	6.8	2.90	6.0	1.0	3.1	4.3	0.521	2.654
	9160	2.6	2.52	18.9	3.6	14.8	21.4	1.251	2.633
	9161	5.1	3.77	13.8	8.9	36.7	11.7	0.480	2.687
	9162	9.8	3.25	15.2	10.5	41.1	9.0	0.542	2.676
	9163	2.7	2.74	6.9	1.7	14.9	6.8	0.503	2.732
	9164	0.9	3.17	9.6	3.5	17.2	6.7	0.766	2.767
	9165	2.6	2.44	17.6	4.0	16.3	21.3	1.420	2.628
	9166	12.9	4.10	22.2	12.3	49.9	18.2	0.888	2.761
Note 3	9167	11.4	2.66	11.1	4.7	25.9	24.2	0.402	2.652
	9168	9.2	3.27	21.3	13.9	46.0	17.5	0.847	2.751
	9169	9.0	3.59	19.3	14.3	45.0	11.8	0.703	2.774
	9170	11.1	2.88	16.8	7.8	40.8	18.8	0.806	2.687
	9171	1.1	2.37	10.6	2.2	13.0	13.9	0.503	2.686
	9172	12.8	3.10	20.1	11.5	47.0	11.8	0.663	2.774
	9173	2.5	2.50	10.6	0.9	10.3	11.2	0.725	2.676
Note 4	9174	2.3	1.55	10.0	0.1	47.2	5.7	0.603	2.671
	9175	11.0	3.30	23.5	13.7	46.8	19.5	0.989	2.651
	9176	12.4	3.13	25.1	12.2	48.9	16.2	0.786	2.663
	9177	1.9	2.27	8.5	0.1	9.7	5.7	0.402	2.689
	9178	9.9	3.43	17.4	12.0	43.4	12.8	0.786	2.666
	9179	0.5	2.45	6.7	1.1	3.8	5.9	0.705	2.634
	9180	0.3	2.89	5.1	1.5	4.3	6.3	0.929	2.652
	9181	1.4	2.65	13.4	3.3	11.4	8.1	1.709	2.586
	9182	1.2	2.64	13.7	3.8	10.3	8.5	1.895	2.572
	9183	0.4	2.37	6.7	0.8	2.9	5.5	0.746	2.627
	9184	1.8	2.36	8.0	1.6	6.7	9.3	1.255	2.597
	9185	0.6	2.78	7.5	1.9	6.8	6.4	0.888	2.621
	9186	3.7	2.58	8.4	1.6	10.4	5.6	0.847	2.650
	9187	3.0	2.23	8.7	0.7	7.4	13.1	0.583	2.716
	9188	0.9	2.86	6.9	1.2	5.9	10.2	0.543	2.688
	9189	0.8	2.23	6.7	0.6	3.9	8.3	0.543	2.675
	9190	1.8	1.83	6.3	0.5	2.0	4.1	0.361	2.670

	SAMPLE	P 75 um	FM P 4.75 mm	MDA LOSS	MTO ATT.	ASTM ATT.	MgSO4 LOSS	ABS.	BULK Dr.
	9191	7.0	1.92	8.5	1.8	11.0	8.1	0.847	2.672
Note 5	9222	1.2	2.09	8.2	1.5	6.4	15.4	1.461	2.709
	9223	1.9	2.94	7.0	2.8	15.9	8.0	0.422	2.754
	9224	1.1	2.76	7.7	1.7	10.9	8.3	0.563	2.730
	9225	3.6	1.54	8.8	-	4.6	8.5	0.886	2.750
	9226	6.8	2.97	9.6	4.8	21.6	7.6	0.847	2.729
	9227	3.6	2.98	8.3	2.8	17.6	7.9	0.969	2.727
	9228	7.7	2.87	12.5	5.8	24.8	14.9	2.270	2.648
	9229	5.5	1.14	7.1	-	4.0	4.2	0.604	2.795
	9230	2.8	2.26	7.5	0.7	7.5	5.7	0.725	2.735
Note 6	9231	1.2	2.39	4.0	0.5	4.7	10.5	0.480	2.661
Note 7	9232	2.0	2.51	7.2	1.8	9.9	14.3	0.766	2.661
	9233	3.4	2.67	11.0	1.8	17.8	9.5	1.092	2.672
	9234	0.6	2.28	6.2	0.5	2.4	6.3	0.561	2.663
	9235	1.6	2.83	6.2	3.2	12.8	9.3	1.051	2.655
	9236	2.4	3.11	6.1	2.4	13.5	6.9	0.766	2.687
	9237	3.2	2.85	9.6	2.5	14.9	9.6	1.337	2.619
	9238	3.4	2.11	7.2	0.2	6.4	5.3	0.402	2.660
	9239	2.3	2.21	6.2	0.9	6.5	7.5	0.341	2.649
	9240	1.1	2.62	5.0	0.4	5.1	5.0	0.280	2.632
	9241	0.8	1.90	4.9	0.3	1.9	3.3	0.320	2.639
	9242	1.5	2.53	6.0	0.2	5.6	9.3	0.381	2.654
	9243	1.6	2.72	6.7	0.2	10.2	7.0	0.281	2.705

P 75 um = material passing 75 um sieve in %; **FM P 4.75 mm** = Fineness modulus of material passing 4.75 mm sieve; **MDA LOSS** = Micro-Deval abrasion loss in %; **MTO ATT** = Ministry of Transportation attrition test loss in % (MTO LS 614); **ASTM ATT** = ASTM C 1137-90 attrition loss in %; **$MgSO_4$ LOSS** = Magnesium sulphate soundness loss in %; **ABS.** = 24 hour water absorption in %; **BULK Dr** = Bulk relative density.

Data not used in analysis:

1 Granulated blast furnace slag, lightweight aggregate.

2 Very fine asphalt sand, only one sieve fraction tested in $MgSO_4$.

3 Sandstone screenings which gave unchacteristic high sulphate soundness loss and relatively low micro-Deval loss.

4, 5 Very fine asphalt sand, only two sieve fractions tested in $MgSO_4$.

6,7 Contains sandstones which gave uncharacteristic high sulphate soundness loss and relatively low micro-Deval loss.

METHOD OF TEST FOR THE RESISTANCE OF FINE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS

1. SCOPE

1.1 This method covers the testing of fine aggregates to determine their abrasion loss in the presence of water and an abrasive charge. It furnishes information helpful in judging the soundness of fine aggregate subject to weathering action when adequate information is not available from service records.

2. RELEVANT DOCUMENTS

2.1 ASTM Designation C 117, Standard Test Method for Materials Finer Than 75 µm Sieve in Mineral Aggregate by washing.

2.2 ASTM Designation C 136, Standard Method for Sieve Analysis of Fine and Coarse Aggregates.

2.3 ASTM Designation E 11, Standard Specification for Wire-Cloth Sieves for Testing purposes.

2.4 LS-601, Method of Test for Materials Finer than 75 µm Sieve in Mineral Aggregates by washing.

2.5 LS-602, Method of Test for Sieve Analysis of Aggregates.

3. APPARATUS

3.1 MICRO-DEVAL ABRASION MACHINE: A jar rolling mill capable of running at 100 ± 5 rpm (Figure 1).

3.2 CONTAINERS: Stainless steel, micro-Deval abrasion jars having a 5 litre capacity with a rubber ring in the rotary locking cover. Internal diameter = 194 mm, Internal height = 170 mm.

3.3 ABRASION CHARGE: Stainless steel balls with a diameter of 9.5 ± 0.5 mm. Each jar requires a charge of 1250 ± 5 g of balls.

3.4 SIEVES: Sieves of 200 mm diameter with square openings, and of the following sizes conforming to ASTM E 11 specifications:

2.36 mm
1.18 mm
600 µm
300 µm
150 µm
75 µm

A 305 mm diameter 75 µm sieve is to be used for washing the aggregate. A 305 mm diameter 6.7 mm sieve will be found useful for separating the steel balls from the aggregate.

3.5 OVEN: An oven capable of maintaining a temperature of 110 ± 5 C.

3.6 BALANCE: A balance or scale accurate to 0.1 g.

3.7 STANDARD REFERENCE AGGREGATE: A supply of standard screenings available from a special stockpile established by the Soils and Aggregates Section, Ministry of Transportation, 1201 Wilson Avenue, Downsivew, Ontario, M3M 1J8.

4. SAMPLE PREPARATION

4.1 Aggregate for the test shall consist of material passing the 4.75 mm sieve (fine aggregate). Split a representative 700 g sample for the micro-Deval test and place in a sealed container.

4.2 A second sample of 250 g (or 125 g if the sample has very fine or uniform grading) is required for determination of gradation. Split off the sample and place in a second sealed container.

5. PROCEDURE

5.1 Wash both the 700 g and 250 g samples separately over a 75 µm sieve until the wash water is clear, as described in MTO Method LS-601, Method of Test for Materials Finer Than 75 µm Sieve in Mineral Aggregates by washing.

5.2 Oven dry the samples to constant mass, usually overnight.

5.3 To calculate the fineness modulus (F.M.) sieve the 250 g sample of the fine aggregate split from the original sample through the required nest of sieves on a mechanical shaker, following LS-602, Method of Test for Sieve Analysis of Aggregates.

5.4 Weigh out a representative 500 ± 5 g sample from the original 700 g. sample. Record the Mass 'A' to the nearest 0.1 g.

NOTE: In cases of dispute about the accuracy of the testing, the sample shall be washed, sieved, made up to an F.M. of 2.8 using the following gradation and then tested:

Pass 4.75-Retained	2.36 mm	50 g
Pass 2.36-Retained	1.18 mm	125 g
Pass 1.18-Retained	600 µm	125 g
Pass 600-Retained	300 µm	100 g
Pass 300-Retained	150 µm	75 g
Pass 150-Retained	75 µm	25 g
		500 g

5.5 Saturate the sample in tap water for 24 ± 4 hours.

5.6 Pour off the excess water and place the sample in the micro-Deval abrasion container with 1250 ± 5 g of steel balls and 750 ml of tap water. Place the micro-Deval container on the machine.

5.7 Run the machine at 100 ± 5 rpm for 15 min. ± 10 sec.

6. QUANTITATIVE EXAMINATION

6.1 Remove the balls from the sample by passing the sample and water through a 305 mm diameter 6.7 mm sieve. Wash the aggregate over the 305 mm diameter 75 µm sieve, according to the procedure described in LS-601, being careful not to lose any retained 75 µm material.

6.2 Oven dry the sample to a constant mass, usually overnight.

6.3 Weigh the sample to the nearest 0.1 g. Record the Mass 'B'.

7. CALCULATIONS

7.1 Calculate the F.M. of the fine aggregate by adding the cumulative percentages retained on each of the following sieves and dividing the sum by 100: 150 µm, 300 µm, 600 µm, 1.18 mm and 2.36 mm.

7.2 Calculate the micro-Deval abrasion loss, as follows, to the nearest 0.1%:

$$\text{Percent Loss} = ((A - B)/ A) \times 100$$

8. USE OF A REFERENCE MATERIAL

8.1 Every 10 samples, but at least every week in which a sample is tested, a sample of the standard reference aggregate shall also be tested. The material shall be taken from a stock supply and prepared according to the following procedure: The material shall be sieved into separate sizes, then thoroughly washed, and dried to a constant mass. The reference sample shall be made up to a fineness modulus of 3.33 using the following gradation:

Pass 4.75-Retained	2.36 mm	100 g
Pass 2.36-Retained	1.18 mm	150 g
Pass 1.18-Retained	600 µm	125 g
Pass 600-Retained	300 µm	75 g
Pass 300-Retained	150 µm	40 g
Pass 150-Retained	75 µm	10 g
		500 g

8.2 Control chart use: The percent loss of the last twenty samples of reference material shall be plotted on a control chart in order to monitor the variation in results (Figure 2).

9. REPORT

The Report shall include the following:

9.1 The F.M. of the pass 4.75 mm material to the nearest two decimal places.

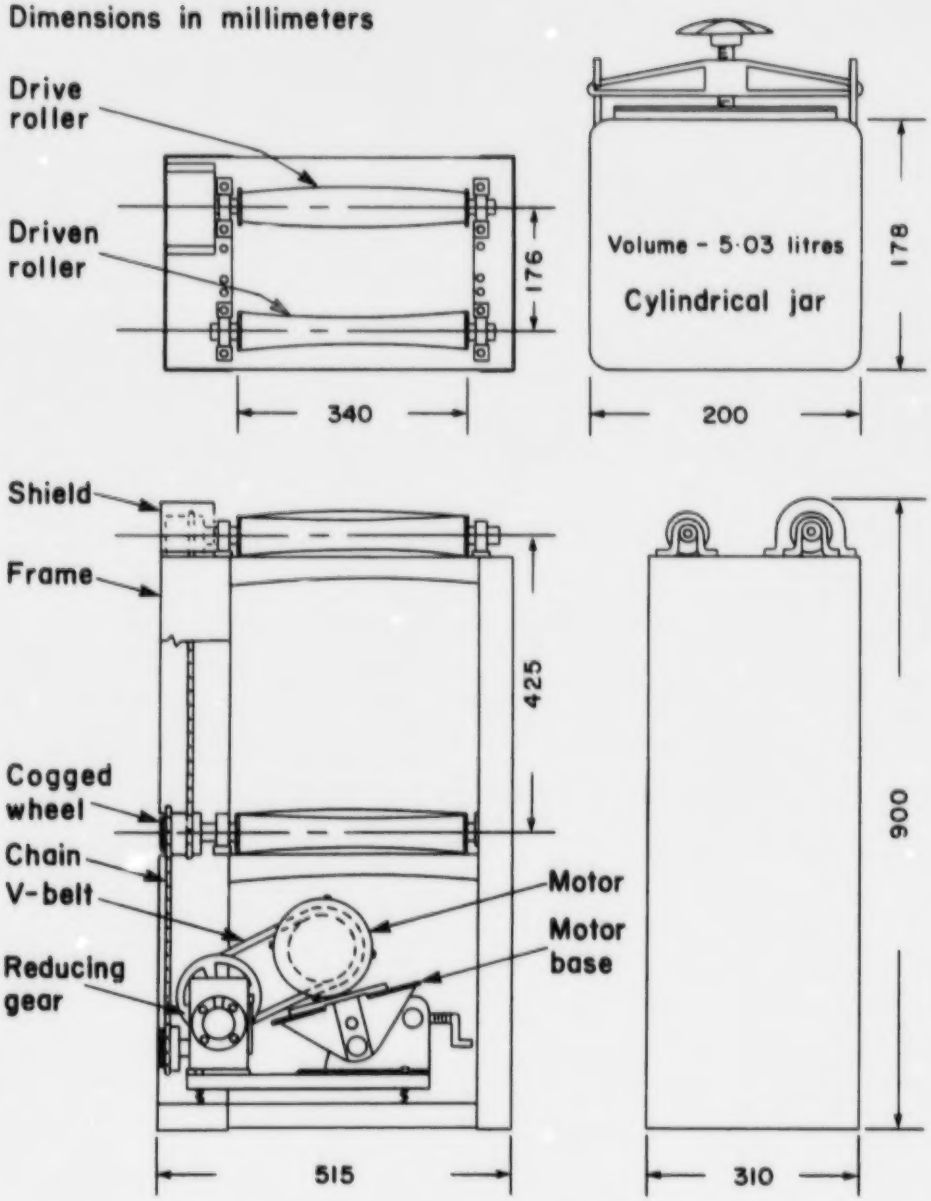
9.2 The percent loss of the test sample to one decimal place.

9.3 The percent loss of the reference sample, tested closest to the time at which the aggregate sample was tested, to one decimal place.

9.4 The percent loss of the last twenty samples of reference material on a control chart (Figure 2).

10. PRECISION

At present this test has not been submitted to a formal multi-laboratory study. A simulated study has been conducted using different equipment and different operators within a single laboratory. For materials with a micro-Deval loss of between 5 and 31%, the average multi-equipment/operator coefficient of variation has been found to be 3.2%. Therefore results of two properly conducted tests on different equipment by different operators on samples of the same aggregate should not differ from each other by more than 9.1% of their average nineteen times in twenty.



Micro-Deval Abrasion Machine and Container

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Ontario

MICRO - DEVAL ABRASION TEST

LAB. NO.	DUE DATE	ORIGINAL MASS g	MASS AFTER TEST g	LOSS g	PERCENT LOSS	PASS 4.75 F.M.

DATE _____ OPERATOR _____ CONTROL NO. _____

REMARKS

PH-CC-448 90-08

TEST DATA CARD

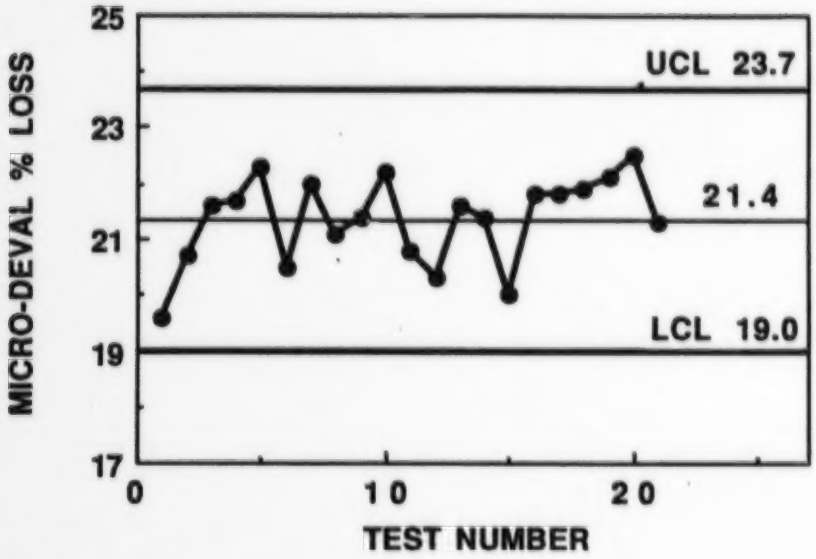

Figure 2

Control chart showing average micro-Deval loss and variation in results for twenty tests of the standard reference aggregate.